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AN OVERVIEW OF THE NEURON RING MODEL

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ABSTRACT

The Neuron Ring model employs an avalanche structure with two important distinctions at the neuron level. Each neuron has two memory latches; one traps maximum neuronal activation during pattern presentation, and the other records the time of latch content change. The latches filter short term memory. In the process, they preserve length 1 snapshots of activation history. The model finds utility in pattern classification. Its synaptic weights are first conditioned with sample spectra. The model then receives a test or unknown signal. The objective is to identify the sample closest to the test signal. Class decision follows complete presentation of the test data. The decision maker relies exclusively on the latch contents.

This paper presents an overview of the Neuron Ring at the seminar level. The appendix contains the information in slide format.

REFERENCES

1. Grossberg, S., "Some Networks that can Learn, Remember, and Reproduce any Number of Complicated Space-Time Patterns I," *Stud.Appl.Math*, vol. 49, 1970.
2. Hecht-Nielsen, R., "Nearest Matched Filter Classification of Spatiotemporal Patterns," *Appl.Optics.*, vol. 26, pp. 1892-1898, 1987.
3. Taber, R., and Deich, R.O., "Fuzzy Sets and Neural Networks," NASA Proc. First Joint Workshop on Neural Networks and Fuzzy Logic, Houston, Texas, April, 1988.
4. Taber, R., Deich, R.O., Simpson, P.K., and Fagg, A.H., "The Recognition of Orca Calls with a Neural Network," Int. Workshop on Fuzzy System Applications, Kyushu Institute of Technology, Iizuka, Japan, August, 1988.

5. Taber, R., "The Evolving Neuron and Fuzzy Logic," Approximate Reasoning Tools in Artificial Intelligence, Ed. Verdegay, J.L. and Delgado, M., Verlag TUV Rheinland, Köln, Germany, January, 1990.

APPENDIX

The next fifteen pages are slides describing the Neuron Ring model.

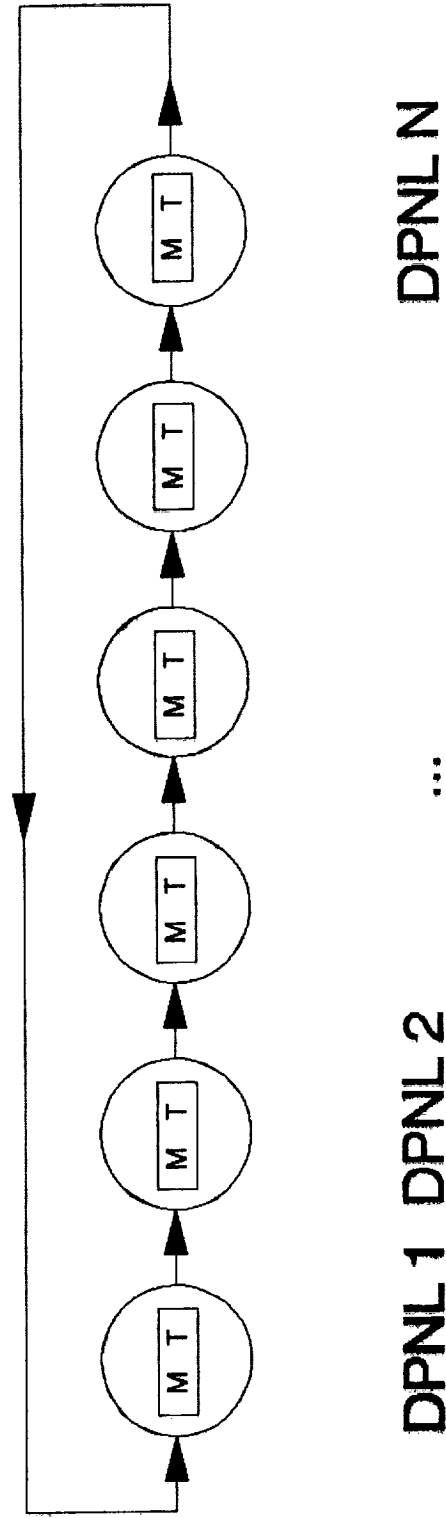
NEURON RING

SPATIOTEMPORAL PATTERN RECOGNIZER

- **EVOLVED FROM GROSSBERG AVALANCHE**
- **DEVELOPED BY TABER, DEICH 1987**
- **USES NEW NEURON CALLED DPNL**
 - **Dot Product Neuron with Latches**
- **DEFINITION: SPATIOTEMPORAL PATTERN**
 - **A PATTERN EQUIVALENT TO A SECTION OF A SONG**

NEURON RING

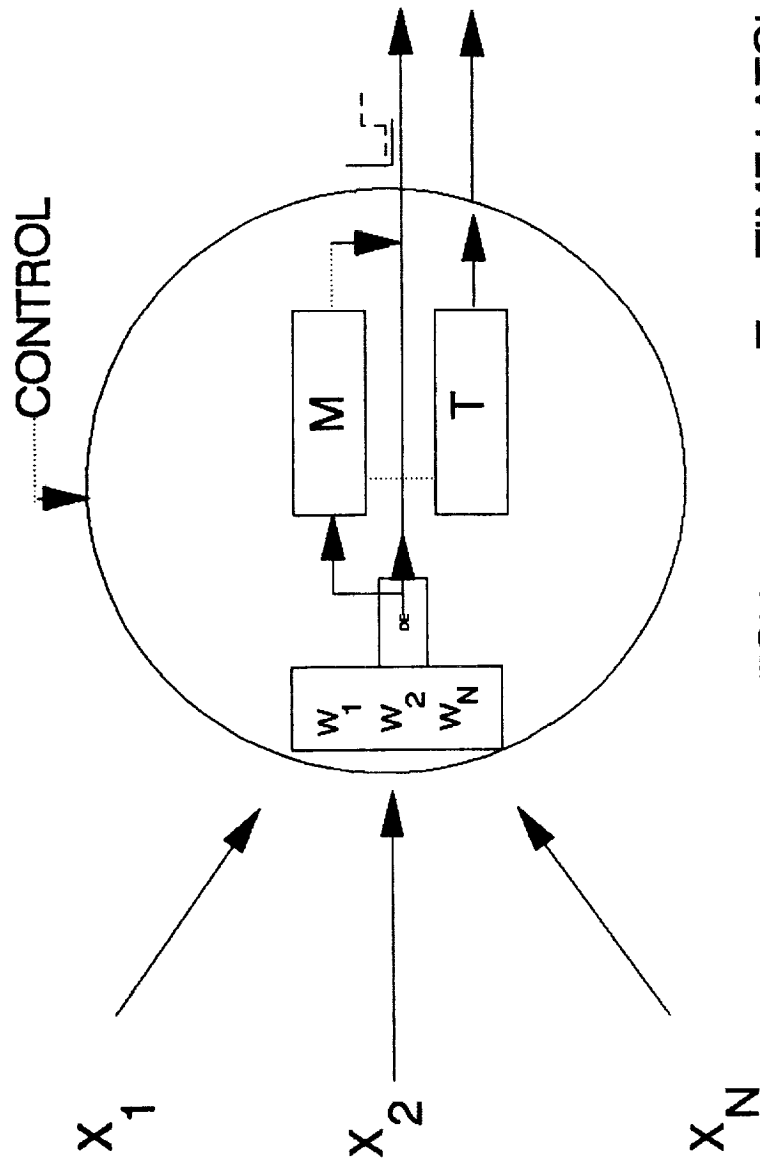
GROSS ARCHITECTURE



SINGLE RING FOR A SINGLE SIGNAL

DOT PRODUCT NEURON WITH LATCHES

INTERNALS



M = MAX LATCH T = TIME LATCH

DE = DIFFERENTIAL EQUATION FOR DX/DT

NEURON RING

DIFFERENTIAL EQUATION IN DIFFERENCE FORM

$$\bullet X_i^{\text{NEW}} = X_i^{\text{OLD}} + A(-aX_i^{\text{OLD}} + b[I_i^1 + I_i^2])$$

= DOT PRODUCT OF WEIGHTS AND ACTIVATION

$$[e]^+ = 0 \text{ IF } e \leq \phi \quad \text{ELSE } [e]^+ = e$$

$$A(e) = e \text{ IF } e > \Omega \text{ ELSE } A(e) = ce$$

A = ATTACK FUNCTION

b = AMPLIFICATION FACTOR

c ϕ Ω = CONSTANTS

NEURON RING

TRAINING

- TRAINING IS FAST
 - IN DIAGRAM WEIGHTS ARE INTERNAL TO DPNL
 - WEIGHT VECTOR = TEMPLATE
 - ACTIVATE CONTROL LINES
 - COPY TEMPLATE TO THE WEIGHT REGISTERS
 - DEACTIVATE CONTROL LINES
 - RING IS READY FOR EXCITATION
- WORKS BEST IF TEMPLATE = CENTROID OF PATTERN CLASS
 - CENTROID CAN BE FOUND VIA AVQ

NEURON RING

FUZZY POST-PROCESSING

- ANALYSIS IS BASED ON [M] AND [T] LATCHES
THESE DRIVE CHIP OUTPUT LINES
- DOT PRODUCT IS MEASURE OF SIGNAL-TEMPLATE
MATCH
- IF EACH SIGNAL-TEMPLATE PAIR MATCH THEN
DONE
- USUALLY, PERFECT MATCH IS NOT POSSIBLE
- NEXT BEST THING IS TO ESTIMATE DEGREE OF
MATCH
 - THIS IS DONE VIA FUZZY THEORY

NEURON RING

FUZZY THEORY

- EACH DPNL CONTAINS WEIGHT VECTOR = SIGNAL SECTION
 - DPNL 1 CONTAINS FIRST X MILLISECONDS OF SIGNAL
 - DPNL 2 CONTAINS SECOND X MILLISECONDS
 - DPNL N CONTAINS LAST X MILLISECOND SLICE
- EACH DPNL IS A MINATURE FEATURE DETECTOR
- EACH DPNL RECEIVES, DURING COURSE OF ACTIVATION, ALL OF THE TEST SIGNAL
- THEREFORE
 - N DPNLs IN A RING GENERATE N ACTIVATIONS EACH
- AT END OF ACTIVATION
- THIS IS KEY:
- EACH M LATCH CONTAINS A MEASURE OF BEST MATCH

NEURON RING

POSSIBILITY DISTRIBUTION AND SIGMA-COUNT

- IMAGINE ALL DPNLS FULLY EXCITED AFTER TEST PRESENTATION

- PERFECT = $(1, 1, 1, \dots, 1)$
- BUT WE HAVE:
- OBSERVED = $(M_1, M_2, M_3, \dots, M_N)$
- WHERE M REAL NUMBER IN $(0, 1)$

- COMPUTE POSSIBILITY (OBSERVED IS PERFECT)

- $\text{POSS}(O \text{ IS } P) = \text{OBSERVED} \cap \text{PERFECT} = \text{PAIRWISE MIN}$
- THEREFORE $\text{POSS}(O \text{ IS } P) = \text{OBSERVED } M \text{ VECTOR}$

NEXT STEP: COMPUTE ZADEH'S Σ -COUNT = DEGREE OF MATCH

NEURON RING

SIGMA-COUNT = DEGREE OF SIGNAL-TEMPLATE MATCH

- **Σ -COUNT = FUZZY SET CARDINALITY = ARITHMETIC ADDITION**
- **EXAMPLE:**
 - **$F = \{.1 \ .2 \ .6\}$**
 - **$\Sigma(F) = .1 + .2 + .6 = .9$**
 - **$\%MATCH = 100(\Sigma COUNT \backslash PERFECT)$**
- **EXAMPLE:**
- **$\%MATCH = 100(.9 \backslash 3) = 30\%$**
- **WE WOULD SAY THIS RING MATCHES THE TRAINING TEMPLATE TO DEGREE .3**

NEURON RING

EXTENSION TO MULTIPLE SIGNALS

- GENERATE 1 RING PER SIGNAL
 - EXCITE EACH RING WITH SAME TEST SIGNAL
 - FORM TABLE, ONE ROW PER SIGNAL

Σ	
RING 1	
RING 2	
...	
RING N	

NEURON RING

MULTIPLE SIGNALS

- FORM VECTOR $Q = \{\Sigma \Sigma \dots \Sigma\}$
 - FORM $R = Q \backslash \text{MAX}(Q)$
 - BAYES DECISION RULE:
 - TEST SIGNAL = SIGNAL I IF $\Sigma_i = \text{MAX}(R)$
 - FIND MAX VALUE IN VECTOR R, INDEX IS THE SIGNAL
- (MAX OF R WILL BE 1!)

NEURON RING

NOTES

- ORDERED VECTOR R IS NOT PROBABILITY !
- EACH ELEMENT IN R IS SUPPORT FOR THE HYPOTHESIS: THE SIGNAL IS i
- PROBABILITY WOULD REQUIRE WE HAVE OTHER INFORMATION
- WE DON'T - JUST ACOUSTIC SIGNATURES

NEURON RING

FURTHER REFINEMENTS

- SAMPLING PHASE TOLERANCE FOR SINGLE RING
- T LATCH WITHIN DPNL CONTAINS TIME THE MAX LATCH CHANGED
 - FORM VECTOR $U = \{T_1, T_2, T_3, \dots, T_N\}$
 - U SHOULD BE IN ASCENDING ORDER
 - EXAMPLE $U = \{1 \text{ PM}, 2 \text{ PM}, 3 \text{ PM}, \dots\}$
 - IF NOT, TEST SAMPLE SECTIONS RECEIVED OUT OF ORDER
 - SORT U TO DISCOVER ORDER
 - SUPPOSE $U = \{2 \text{ PM}, 1 \text{ PM}, 3 \text{ PM}\}$ THEN INSTEAD OF ABC, WE RECEIVED BAC

NEURON RING

A EUCLIDEAN 2-D METRIC BASED ON M AND T

- WE HAVE THE Σ METRIC ALREADY
- DEVELOP DISTANCE METRIC BY
 - COUNTING # SWAPS NEEDED TO BRING U BACK TO ORDER

$$D_i = [(1-X)^2 + Y_i^2]^{1/2}$$

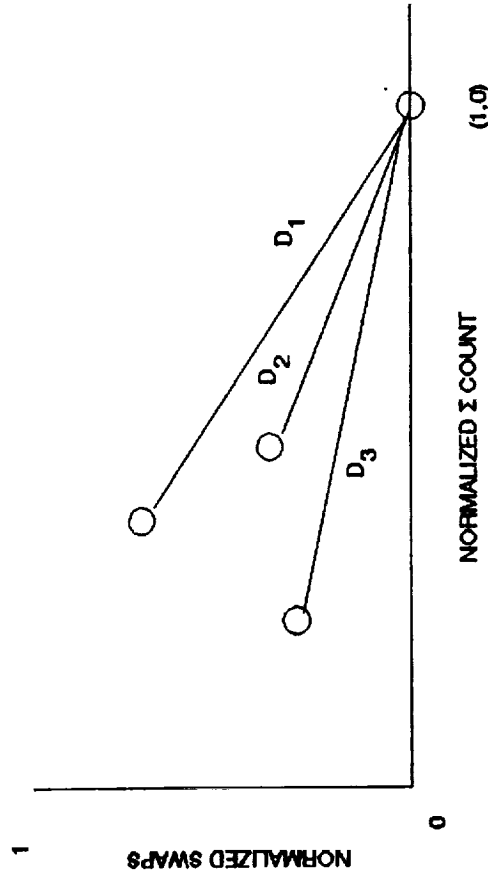
X = NORMALIZED Σ COUNT FOR RING i

Y = NORMALIZED NUMBER OF SWAPS (i.e. #/(N-1) FOR N RINGS)

NEURON RING

2-D DISTANCE METRIC

- IF ALL NEURONS FIRED MAXIMALLY AND IN ORDER OUR METRIC POINT WOULD BE (1,0)
- 1 = MAXIMUM NORMALIZED Σ
- 0 = NO SWAPS REQUIRED
- RESULT OF TEST RUN (X,Y)
- $0 \leq X \leq 1, 0 \leq Y \leq 1$
- DISTANCE AWAY FROM PERFECT ...



SIGNALS MAY FALL INTO NATURAL CLUSTERS
EQUIDISTANT SIGNALS ARE IN THE SAME EQUIVALENCE CLASS

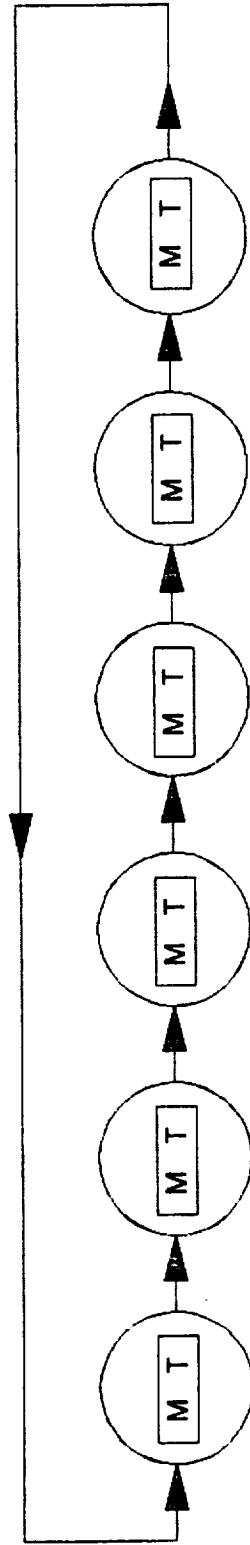
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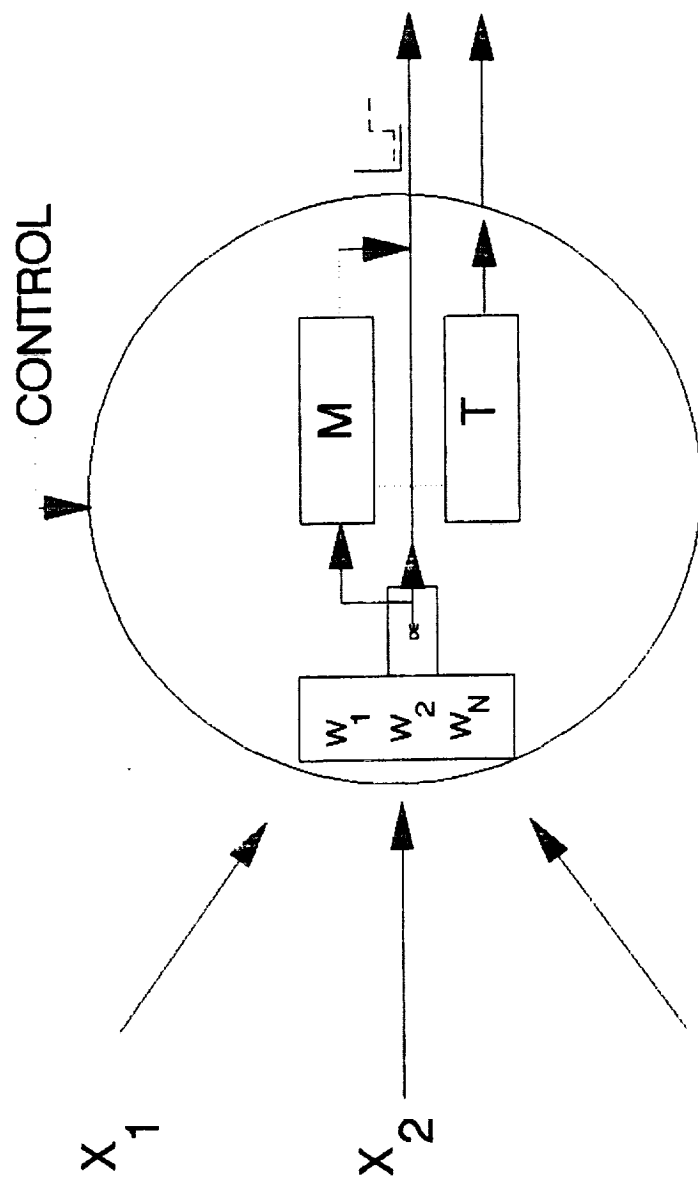
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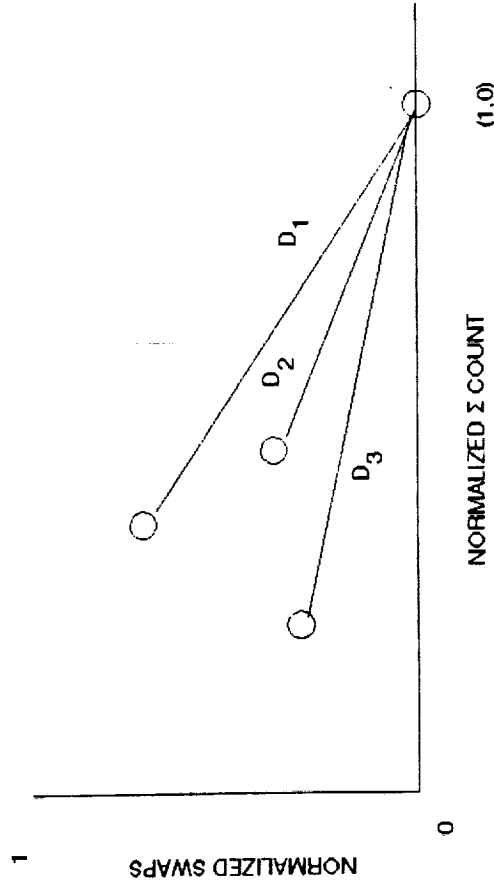
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